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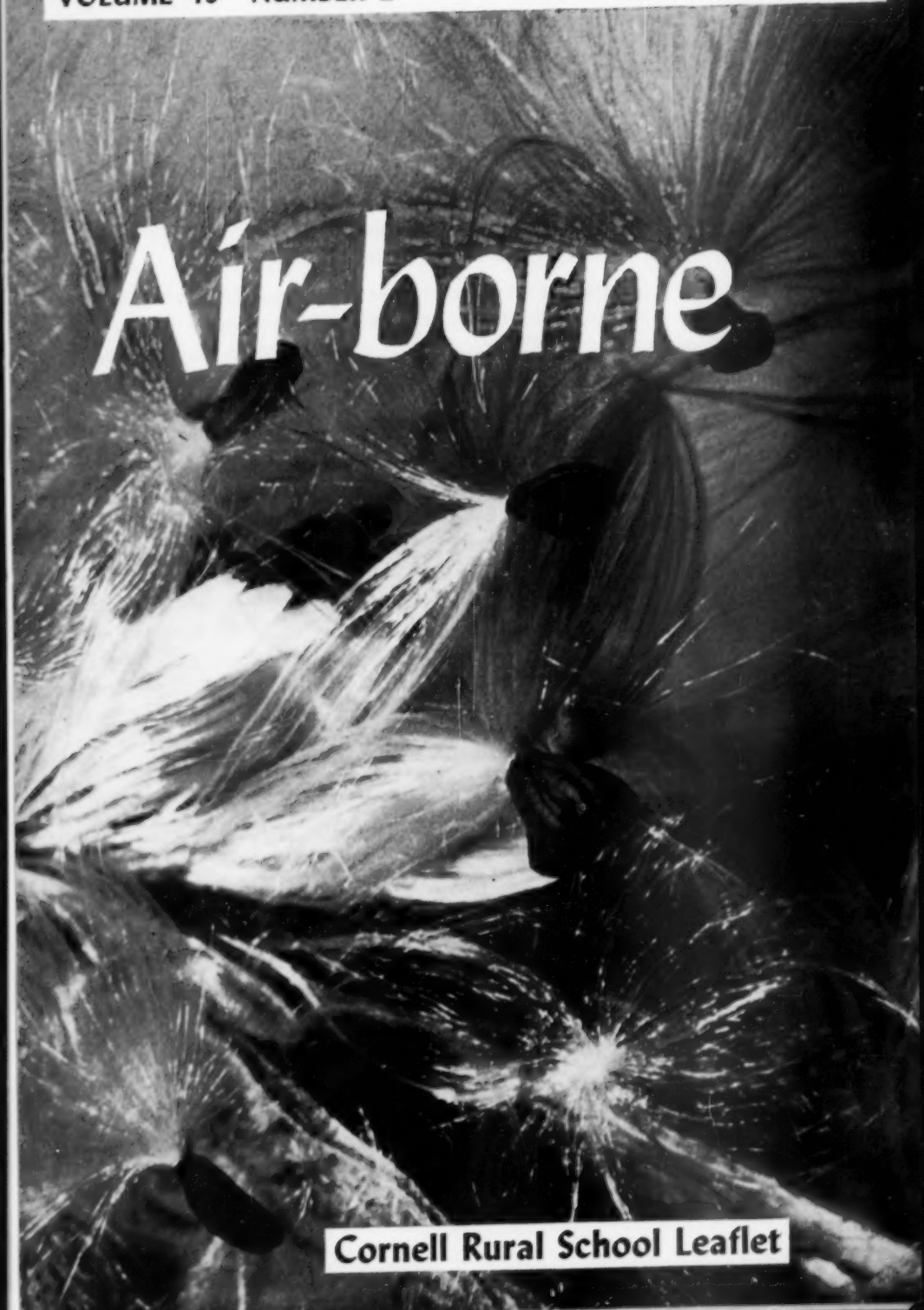
Air-borne



Cornell Rural School Leaflet

AIR-BORNE

By VERNE N. ROCKCASTLE
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A NEIGHBOR of mine once said about his yard, "Where on earth do all the weeds come from? I take them out each year and the next year they're right back again!" He was talking about dandelions, chicory, and thistles. He could take out every weed he found but he couldn't keep new plants from being sown because the fruits of all three of these weeds—and many more—are *air-borne*.

While you have this Leaflet in your hands, look out the nearest window. How many moving things can you see? Are people walking, or cars going down the street? It is easy to see what makes them move. The walkers push their feet against the ground and the car tires push against the pavement. But what does a bird push against when it flies? What moves the leaves on the trees? You can't see it, but you certainly know that *air* is the answer. Did you ever feel the air push against you? Did it help or hinder you?

The air that flows around airplanes, kites, and birds, and also moves sailboats and clouds, acts like very "thin" water. You might think of birds as "swimming" in the air. And a kite is like a surfboard *in* the air ocean instead of on its surface. How many other things can you see the air carry? On some days hats and papers are air-borne; on others, just fog and sound. Why should so many things be air-borne at some times and so few at others?

How many fruits can you find on one head?

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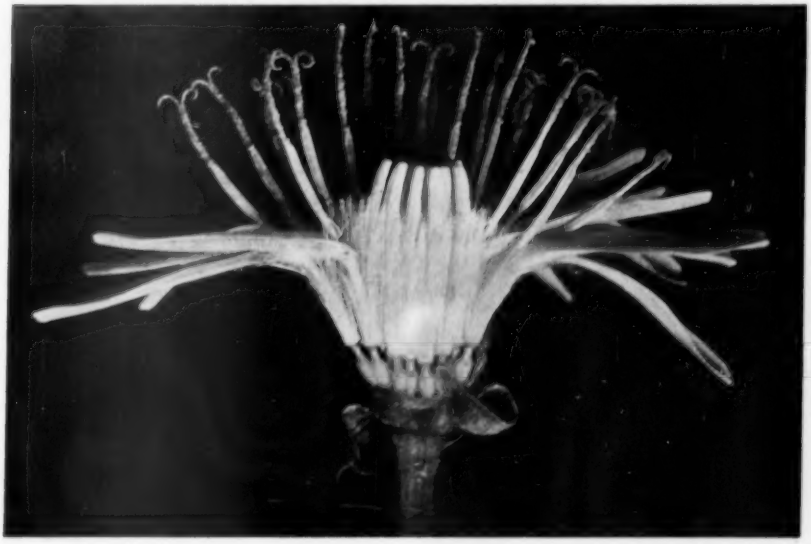
air is still, or out-of-doors when the wind is not blowing. Do the fruits rise in the air, or do they fall slowly? Do these air-borne fruits really float in the air, or does their fuzz just cause them to fall slowly as the breeze carries them away from the plant? How far do you think each of these fruits could be carried by the wind? Maybe by watching some on a still day, then on a slightly breezy day, and again on a windy day you can see just how well these little parachutes carry the fruits away.

Some other composites which you can look for are asters, Joe-pye-weed, hawkweed, and daisies. Do all of these have fuzzy air-borne fruits? Ragweed is a composite whose flowers are not showy like dandelion or thistle. Can you find its fruits in late summer or early autumn? Are these air-borne? As you look around the fields and lawns in autumn, you may be surprised to discover how many plants depend upon the breezes to scatter their fruits or seeds.

Some plants produce air-borne seeds in pods. You probably have seen milkweed growing in fields or along roadsides. Have you ever looked closely at the delicate parachutes its seeds have? Get a milkweed pod in autumn and carefully split it open. What do you see? Does

What parts of each flower become the fruit?



Air-Borne Plants or Plant Parts

Fruits and Seeds

Probably no New York State weed is more familiar than the dandelion. Most of you have blown the fruits from its head to watch them drift away on their tiny parachutes:

"Oh, downy dandelion wings,
Wild-floating wings like silver spun,
That dance and glisten in the sun! . . ."—Gray

The dandelion is one of a large family of flowering plants called *composites*. Many of the composites have air-borne fruits which are much like those of the dandelion. Pick a dandelion blossom and examine it carefully. Each of those yellow parts, which you might call petals, is really a separate little flower! Pinch the blossom in two and notice how each flower has its own bit of fuzz near the bottom. The tiny white bulge at the base of each yellow flower becomes the rough "seed" and the fuzz becomes its parachute. *Air Laboratories*, the Leaflet for fall 1953, told you how to make a little blow-gun from a dandelion stem and some fruits. When you find a dandelion fruit, compare it with one of the little flowers. What part of the flower had to grow the most to make a complete fruit—the ovary (it contains the seed), the stalk, or the fuzz?

When goldenrod and thistle begin to turn white in late summer, look at their fruits. Does the fruit of goldenrod look anything like the fruit of dandelion? Is there a cluster of fuzz on the goldenrod just as there is on the dandelion? Can you see any difference between the two fruits? Which do you think the breeze would carry farther? Now look at the fruits on a thistle plant. Which of the three fruits—dandelion, goldenrod, or thistle—has the most fuzz? Which of the three probably would be carried farthest by the wind? Rub some of the thistledown between your fingers. Isn't it soft and fleecy? Some birds use this material to line their nests. It makes a soft, warm bed for the eggs and for the young birds while they are growing.

Blow away some dandelion, goldenrod, or thistle fruits and watch how they are carried by the breeze. Does the seed hang below the fuzz, or is the fuzz below the seed? Blow off some of the fruits in a room where the

even winters right inside the cattail head. What a snug winter retreat that is!

You can see many plants that have air-borne fruits in the fields in late summer or early autumn. Probably you can think of more than I have mentioned. Keep some records (with little sketches if you can) of the time when the fall composites produce their fruits. See how many fruits are produced and try to tell how far they are carried. Perhaps you can make a list of wind-carried fruits, with the longest-traveling fruits at the top, and those that don't go very far at the bottom. Which of these might be the most troublesome weeds? Why? Do you think it is a good thing that some of these weeds are scattered by the wind? How else would plants reach waste land, roadsides, burned-over woods, and prairies?

Can you find any garden flowers that have air-borne seeds or fruits? If any do, and their seeds spread the plants outside the garden, would the plants still be called garden flowers? When would you consider them weeds instead? Weeds are often described as plants that grow where we don't want them to grow. Do air-borne fruits and seeds help weeds to grow where we don't want them? Your own lawn will give you the answer to this question.

Tree fruits and seeds

Many trees and some shrubs also have air-borne fruits. Have you ever noticed how maple fruits come whirling down from the trees like little helicopters? You can find quantities of them under almost every large maple tree. Look at them carefully. Does a "wing" project from both sides of the seed-bearing part, or from just one side? Can you find two fruits attached to each other? Where were these fastened to the twig? These wings on the maple fruits, like the fuzz on a dandelion, make the fruits descend, or fall, slowly. Then the wind can carry them some distance away. Where would the maple fruits drop on a still day? on a windy day?

The lightest breeze carries Indian hemp seeds

much fuzz show or are the seeds so neatly packed that it looks as if there isn't much but seeds? How many seeds can you count in one pod? Now pick out one seed. Can you count the number of hairs attached to it? If you could multiply this number by the number of seeds you find in the pod, you would discover about how many fuzzy hairs are packed away in one milkweed pod. Your teacher can help you figure this. Suppose you picked out one hair every day. About how long would it take you to pick all the hairs out of one milkweed pod?

Indian hemp is another pod-forming plant. This plant usually grows in moist fields and open wooded areas. In fall its stems become reddish brown. Its bark makes very strong cords when strands of it are twisted. Take home a few of its long slender pods and keep them in a warm room for a few days. What happens to the pods? In what kind of weather do you think these pods open best? Can you count the number of seeds in one of the Indian-hemp pods? Does the fuzz of the Indian-hemp seed surround it, or is it attached at one end of the seed? Is this the same as in the milkweed seed? These light, fluffy fibers not only help to carry the seeds in the air, but help them to float for long distances on water. In fact, during World War II the down of milkweed seeds was sometimes used to stuff life preservers because it was light and fluffy, yet wet-resistant.

Cattails, too, have air-borne fruits. You can see these in almost any pond or marsh or along river banks or ditches. The enlarged brown part at the top of a cattail stalk consists of many hundreds of fruits, each with a seed which may grow into a new cattail plant. Pick one of these brown cattails and bring it to school. Put it in a jar without water and leave it in a warm place. What happens? Do the cattail fruits float along as easily as those of dandelions? Take some of the fruits outdoors and let the wind blow them away. Watch for about ten minutes. How far do the fruits go? Do you think the cattail has as good a parachute as the thistle? Can you guess why moist places soon become covered with cattails although you can't see any growing nearby?

Many birds use these downy air-borne fruits in their nests. Some animals also use them as "blankets" in the winter. The whitefooted mouse is very fond of cattail fuzz for its nest. The caterpillar of a species of moth

The parent trees at the left seeded the field down-wind

seeds and see how they fall. Do they spiral, flip-flop, or spin? Just how do they come to earth?

The conifers have winged seeds, packed away in the cones. As the scales of the cones open, the seeds fall out and spin to earth very much as the maple fruits do. The next time you find a pine cone separate some of the scales and see whether you can find any seeds in the cone. Most pines shed their seeds while the cones are still on the tree, but often a few remain in the cone after it falls. Even in an old cone, you can see where the seeds were. Pull off one scale of a pine cone and look at its upper side. Can you see two brownish hollows near the base of the scale? Each hollow contained a seed whose wing lay flat along the scale. Does your scale look like the picture on page 10?

You have learned about a few plants whose fruits or seeds are air-borne. You can find many more near school or home. The sycamore or button-ball dangles its round clusters of air-borne fruits from its upper branches much like Christmas tree ornaments. The fruits of basswood are attached to curious wings each of which spins several of the round, pea-sized fruits to earth. Winged tree-of-heaven fruits, hop-hornbeam "seeds" in little papery bags, blue beech "seeds," and whole pods of redbud, honey locust, and black lo-

You can have fun with the fruits of some maples that have dropped from the trees. Norway maple fruits are best. These fruits (called *keys* by many persons) have a large wing. Thin walls enclose the seed. When you peel back the walls from either side of the seed, the seed drops out. Then you can stick the keys on your nose as shown in the picture to make "big noses." Can you do this with the keys of silver maple? sugar maple?

Look for a maple tree that stands alone in a yard or field and that has dropped its fruit. Walk around the tree. Are the fruits evenly spread on the ground or are there more in some places than in others? To answer this question, mark out a square yard of ground at several places around the tree and count the fruits in each of these areas. When you have counted the fruits in one area, mark the number on a little card and put the card down in that area. Place a small stone on the card to keep it from being blown away. Do the cards indicate more fruits on one side of the tree than on the other? Can you find fruits farther from the tree on one side than on the others? Do your figures tell you anything about which way the wind blows most of the time? If all the seeds sprouted, where would the most seedlings grow—upwind or downwind from the tree? The picture on page 9 shows a field of Scotch pine which grew from seed produced by the big trees.

Many other trees have winged fruits. The fruits of ash trees are more pointed than those of maples, and the wings are smaller. Do you think the fruits would drift in the air as far as the maple fruits? When the fruits of the ash fall, does the seed end or the wing end hit the ground first? Which position is better for sprouting? Why?

The winged seeds of catalpa trees are held in long pods. Some of these trees probably grow right near your school. Try to get a pod. Open it and count the number of seeds in it. Are there wings on both sides of the seed, or on only one side as in the maples? Drop some of these

My, what a big nose you have!

across the prairie before they finally come to rest.

Pollen

Pollen, like fruits and seeds, may also be air-borne. From spring through early fall, multitudes of insects—many of them air-borne—can be seen carrying pollen from one flower to another. If you stand in a field of clover, in an apple orchard in blossom, or in a patch of goldenrod or asters, you can even hear the "pollen traffic" as the little winged trucks of the insect world transport their pollen. But what of the plants whose flowers are small or that lack the fragrance to attract insect guests? For flowers such as those of the grasses, grains, conifers, and many others, the air alone does what insect guests do for many colorful, fragrant flowers.

Pollen grains, you know, join with ovules of flowers to produce seeds. These grains may be so small that even groups of them look like powder. Individual ones can best be seen with a magnifier. All are somewhat rounded in general shape, but some are spiny, some pitted, some irregular and bumpy, and still others smooth. Each type of plant has its own kind of pollen and scientists can often tell from what kind of flower a pollen grain came by looking at it with a microscope.

Staminate cones of Austrian pine—their "gold-dust" pollen is air-borne

Some air-borne fruits: left to right, top, *sugar maple, red maple, American elm, silver maple;* bottom, right, *Norway maple*

The air may carry pollen many miles—even far out to sea. Persons who are allergic to some kinds of weed pollen (ragweed is a frequent offender) find it difficult to escape the far-carried grains. Even the central Adirondacks, a popular hay-fever retreat, are not entirely free from air-borne pollen grains of many kinds which settle over every section of New York State. If all the pollen grains floating in the

The pitch-pine cone is well-armed with stout spines

cust are air-borne. Willows, poplars, and silver maples produce airborne seeds or fruits in early spring. The cottony seeds of the willows and poplars are much like cattail fruits. Cottonwood trees may produce so many fluffy white seeds that the nearby ground looks snow-covered. Willow seeds are carried long distances by the breeze, but many do not germinate. Others land where they cannot grow. How do willows spread, then? The elm's third springtime "shower" is one of winged fruits, following the first shower of bud scales and the second of the dead flower-parts. Silver-maple keys spin earthward not long after the elm fruits are shed.

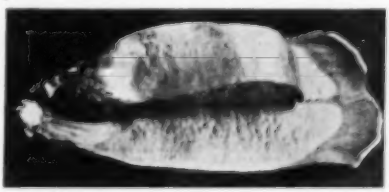
Collections

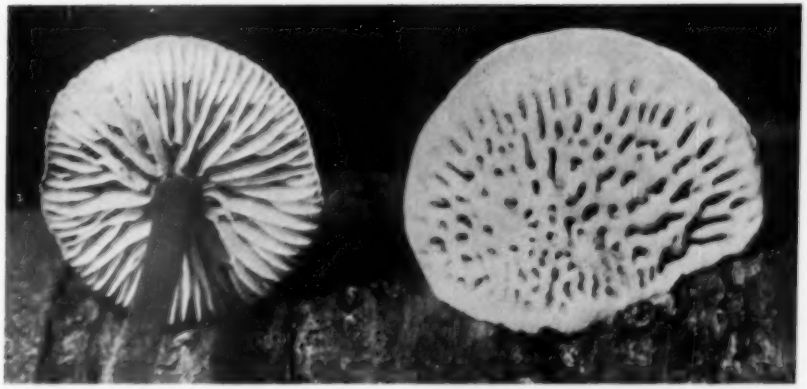
You can make an interesting collection of air-borne fruits and seeds. Put them in little glass bottles or cellophane envelopes and label them. You may wish to learn what sorts of air-borne fruits or seeds are produced at different seasons. When you stand in a park or woods or in a field, how many different air-borne fruits can you see? Carefully look around on the ground in the woods or fields to see how many air-borne things you can find. You know now how some of them got there even if there are no parent plants nearby.

Whole Plants

Sometimes the air carries whole plants. Tickle-grass and some pigweeds are among these air-borne "tumbleweeds" which the wind may roll the length of a field, or even into adjoining fields. They scatter their fruits as they tumble, or drop them when they stop. In the West, some tumbleweeds roll miles

A scale and one seed from a pitch-pine cone





How would spore prints from these two types of fungi differ?

shellac or with one of the plastic sprays now available at stores.

Some mushrooms are *gilled*, which means that on the underside many thin walls extend out from the stem. These walls look a little like the partitions in an orange or a grapefruit. On their walls are the spores which make your spore print. When a mushroom is fully grown, the spores fall downward between the gills and into the currents of air near the ground. Then they are borne up and over the fields and woods until they come to rest on the ground. Millions of spores may be produced by one mushroom. How many do you think grow to become new mushrooms?

Other mushrooms have *pores* instead of gills. The spores of these mushrooms fall down through the tube-like pores and into the air below. They are then carried away like the spores from gills. What would a spore print from one of these fungi look like?

Fungi which look like shelves sometimes grow on tree trunks and stumps. These *bracket*, or *shelf*, fungi produce spores as do the mushrooms on the ground. Look at the white underside of a shelf fungus and see whether it has pores or gills. Why is it an advantage to the shelf fungus to be high above the ground? Where would the spores go if the fruiting body of the fungus were flat on the ground?

Puff-balls, another group of fungi, grow right on the ground. They are round and nearly stemless. They vary from small marble-like balls to basketball size. When they are white inside, they are good to eat. When they

air in spring, summer, and fall were visible, what pollen storms you would encounter! Those you may see around pine trees or cornfields at certain seasons may give you some idea. Insects are valuable pollinators, but the air is certainly just as important.

Spores

Most of the plants which grow around your home and school have true flowers and produce fruits or seeds. But many plants never have flowers and cannot produce seeds. Among these are the fungi, the mosses, and the ferns. They produce many tiny round *spores*, that, like seeds, can grow into new plants if they find the right conditions. Spores are usually very tiny—so small that several hundred could fit on a pinhead. Spores are air-borne and may be carried even farther than cattail or thistle fruits.

You can see for yourself how small and easily air-borne some fungus spores are. Moisten a piece of bread and put it in a box or jar or can in a dark place where it won't dry out. Leave it for a few days, then look at it. Do you find any fuzz on it? What do people call this fuzz? It was produced by spores too small to be seen. Some are always afloat in the air. Do you see why it is so difficult to prevent mold if the conditions for its growth are present? Spores of molds can get into cans, bottles, and all sorts of containers that aren't tightly sealed. If some spores should be in the cans before they are sealed, what can happen? How can this be prevented?

Mushrooms and other fungi

Mushrooms and many other fungi produce many thousands of tiny air-borne spores. These spores are too small to be seen clearly without a magnifier, but you can see the color of some of them by making a spore-print. Cut off the umbrella-like top of a fresh mushroom and lay it underside down on a sheet of paper. Cover it with a box or glass dish so no breeze will disturb it. After a day or two carefully lift the box or glass and the mushroom off the paper and you probably will see a beautiful spore print. What color are the spores of your mushroom? Spores vary in color from white, through pink, purple, brown, and black. On what color of paper would a print of white spores show well? No known spores are blue, so you can use light blue paper for all your prints. You can preserve your prints by spraying them with

parent plant. Wet spores would be more difficult to transport and might germinate too close to the parent plant to have room to grow.

By following the directions in *Indoor Nature Studies* (the Teacher's Leaflet for Fall 1954), you can make a terrarium in which to put several different kinds of moss to watch through the winter. Then you can see for yourself how mosses grow, and how the capsules and their "hats" develop. The study of mosses is a fascinating one, and mosses are easy to collect at almost any season.

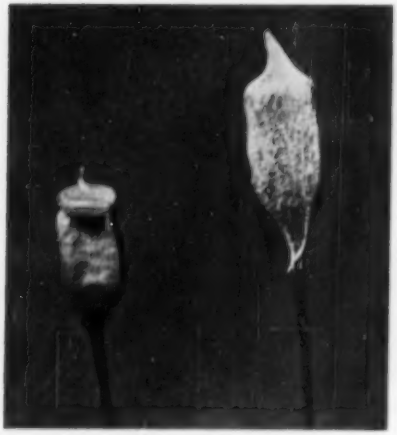
Ferns

The spores of many kinds of ferns are borne in tiny clusters on the underside of the fern leaves, or *fronds*. Look for these little spore-bearing dots (called *sori*) on fern fronds in autumn. Are the sori of all ferns the same size and shape? Do all fern fronds show sori (singular, sorus) on their undersides? Can you find any sori which seem to be partly covered by a little flap, called an *indusium*? These flaps and the shape of the sorus are a big help in identifying some ferns. Each sorus is really a cluster of tiny, stalked capsules—much smaller than the moss capsules. On dry days these capsules break and fling out thousands of spores to be air-borne to new fern frontiers.

Photo by Joseph Richert

Marginal shield fern has the sori near the margins

Some ferns produce their spores on shoots which are different from the leaf-like fronds. Sensitive and ostrich ferns are two examples. In winter you often see the stark brown spore-bearing shoots of sensitive fern projecting above the snow, marking the place where last year's leaves lie withered. You might pick one of these, take it home, and shake some of the spores onto the surface of a glass of water. Cover the glass, and place it in a cool spot where it will not be disturbed. You may be lucky enough to see the spores germinate into new green fern plants. Few people ever see this tiny prelude to the large



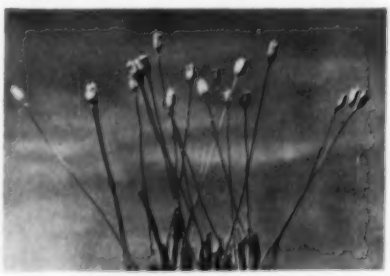
Hair-cap moss—the capsule at the left has lost its "hat"

ripen, the whole inside is filled with spores which are shed in brownish puffs if the fungus is pressed or squeezed. A giant puffball may shed as many as ten trillion spores! Can you write this figure? If all of these spores grew into new giant puffballs, the second generation would occupy a space about one thousand times the size of the earth! You can certainly see that only a tiny fraction of puffball spores grow into new puffballs.

Mosses

Mosses have an interesting manner of releasing spores. From the top of many moss plants grow thin, springy stalks each topped by a swelling called a *capsule*. Some common moss capsules are shown on this page. In these capsules are produced spores which take the place of seeds in mosses. Mosses have remarkable devices for opening the top of the capsule and releasing the spores inside. Look closely at some of these capsules. A magnifier will help you to see the smaller parts. Does a pointed "hat" cover some of the capsules? On hair-cap moss this "hat" is tall, pointed, and fuzzy. When you pull it off, you may be able to see still another lid on the capsule. Under this lid are some tiny teeth which can close the open end of the capsule and keep the spores from falling out. On dry days these teeth bend away from the opening and let the ripe spores fall out. On moist days they cover the end of the capsule so spores cannot be released. In this way spores are shed on dry days when they can be easily air-borne and carried some distance away from the

Hair-cap moss is sometimes called "pigeon wheat." Can you tell why?



Birds

You have learned about some plants or plant parts that are air-borne. Many animals, too, move around in the air. Of these, you are probably most familiar with birds. Do you know what makes them able to fly or to soar so well? Watch the next few birds you see. Does any one soar like a glider? flap its wings steadily? fly in spurts? fly in a straight line? take an undulating (up and down) path? Do birds take off or land against the wind, or with the wind? Do the wings of a bird move together or do they alternate? By watching carefully how birds use their wings, you can learn much about air currents and flight.

The feathers of a bird are amazingly complex. The next time you find a wing feather, examine it carefully with a magnifier. If you can use a microscope, examine the feather with it. You will see that the feather is made up of a central *shaft*, with many side branches called *barbs*. These barbs together make up the flat portion called the *vane*. Look closely at one of the barbs. You will see that it has many tiny hooks or *barbules* which hook over similar parts of the next barb. So the barbs of a wing feather are all hooked together to make a light, yet strong, fan-like structure. If you pull two barbs apart, the vane will separate. But a bird can run its bill over these barbs and they will hook back together again. Thus the bird can keep its flight feathers in good condition by frequent *preening*. A flight feather is only one kind of feather. How many others can you find? You might make a feather collection. Are those you find mostly of one kind? Which kind are they? Birds regularly shed or *molt* their feathers, usually twice a year. So it isn't serious if the bird loses a few flight feathers. Before long, others take their places.

A small section of feather magnified—A, barb; B, barbicel; C, barbule

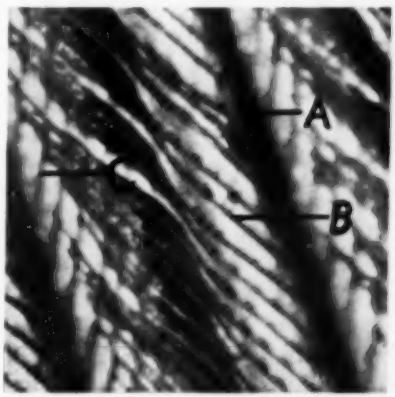


Photo by E. L. Palmer

Dead shoots of sensitive fern may contain many living spores

fronds which help to make the summer woods so green.

Perhaps you will want to find out more about how ferns scatter their spores. Look in your library for books that will help you. Do you think fern spores are scattered as easily as those of mosses? May the height of the fern frond make it easier to scatter the spores long distances? Why?

Bacteria

Even smaller than the spores are *bacteria*. They are among the smallest of living things and are easily carried long distances by the air. They can travel on bits of dust, smoke particles, and tiny water droplets. Can such microscopic organisms be kept out of your home, or your school, or even your body? What would you do to keep bacteria from getting into canned foods? If you open a can, then replace the cover, and seal it again, is the food likely to spoil? Why? Bacteria ride around easily on the droplets of water we spray into the air by sneezing. Sometime when you think you are going to sneeze, do it close to a clean mirror without covering your mouth. Can you see any evidence of moisture on the mirror? Any one of these tiny air-borne droplets may contain thousands of bacteria. Can you see why it is important to cover your mouth with a handkerchief when you sneeze? Does the same thing apply to a cough?

Bacteria that ride around in the air are sometimes harmful to us, but more frequently they are beneficial. As living things grow they remove certain chemicals from the soil and water. When plants or animals die, it isn't long before tiny air-borne scavengers cause them to decay and to return their chemicals to the soil. What would eventually happen if these chemicals were never returned to the soil? You can see that bacteria responsible for decay of dead things are just as important as trees, or grass, or animals.

Florida all the way across the Gulf of Mexico without stopping, its tiny wings beating the air many times a second all the way. On the other hand, the turkey vulture often soars for more than an hour without even flapping its wings. It rides the air currents above fields and woods, rising and falling as it glides. How many other birds do you know that soar like the vulture? How many do you know that cannot soar, even for short distances? What does the house wren do? the crow?

Not all birds use their wings for flying. Some birds cannot fly at all, but swim or run instead. No such birds live here in New York State, but the ostrich and the kiwi of Australia are two that do not fly; they run. The penguins of the Antarctic swim instead of flying. Can you learn about other birds that do not fly?

Not only are birds themselves air-borne, but they are responsible for making many plants or plant parts and some animals air-borne. If you were to make a farm pond right in the middle of a dry field, it wouldn't be long before animals would be living there even though you didn't actually put a single animal in. Some probably arrived by their own means of travel. But it is

Photo by R. B. Fischer

Chimney swifts use their tails as props

believed that birds may carry water insects from one place to another on their feet or feathers. Many tiny plants and animals can be carried from pond to pond in drops of water on a duck or a heron. Seeds, spores, and parasites can all "hitch rides" on birds as they travel from one place to another. They are truly air-borne, even though they are only passengers.

Birds carry many seeds around the country. The seeds of fruits they have eaten may drop to the ground where they can sprout, take root, and grow. Many plants along hedgerows have been "planted" by birds. Why should more plants be found along hedgerows than in open fields?

Insects

The most numerous of all the air-borne animals are the insects. Most insects, like most birds, use

Photo by R. B. Fischer

The herring gull soars with ease

You can see that the shaft of a feather is hollow. This certainly makes the bird lighter than if the shaft were solid. But there are other ways in which birds are made lighter for flying. Their bones are often hollow and many large air spaces or air sacs are connected with their lungs. These air sacs make the bird's lungs more efficient. Birds may look bulky, but remember that part of their bulk is merely air.

Look carefully at the shapes of the wings and tails of birds. Can you see some pointed wings; others that are rounded? Compare the long tail of a grackle with the short tail of a starling. Is the tail of the meadowlark long or short? Does the length of the tail tell you anything about how a bird flies? Do birds with short tails usually fly as gracefully as those with longer tails? The tails of hawks are easy to see against the sky. Does a hawk with a broad tail commonly soar or hover? Do slender tails indicate any particular flying habit? Can you identify some of the hawks by their tail silhouettes?

Some birds use their tails for things other than flying. The woodpeckers, sapsuckers, and flickers prop themselves with their tails while they peck away at trees. How would a chimney swift use its tail? the nuthatch? the brown creeper? Frequently birds use their tails to help them balance on twigs and wires. Their tails also help them stop at a perch or a nest. Their tails act like landing flaps on an airplane wing to slow them down. How many other ways in which birds use tails can you think of?

In zoos, or on farms where geese and ducks are raised, it is frequently necessary to clip the wings to keep the birds from flying away. If the flight feathers are clipped so the bird can't fly, how often must this be done? Remember that birds regularly molt their feathers and grow new ones.

The wings of birds are remarkably efficient structures for flying. The ruby-throated hummingbird, small as it is, flies from

mosquito? punkie? Does the size of the wing indicate anything about its rate of movement? Are the large-winged insects always the faster fliers? Of all the insects you can see, which do you think is the most skilled flier? Can you find slow fliers, such as the fragile crane fly? fast fliers such as the sturdy, speedy dragon-fly? The insects of your garden, lawn, school grounds, or nearby fields or woods will provide many interesting questions —and answers.

All birds' wings have feathers, but the wings of insects differ greatly both in the way they are made and in their materials. The wings of moths and butterflies are covered with tiny scales that overlap like the shingles on a roof. It is these scales which rub off on your hands when you kill a clothes moth or hold a butterfly in your fingers. Adult caddis flies, which as larvae live in water and build strange cases of bits of wood or stone, have hairy wings. The front wings of beetles are thick and hard and cover the delicate hind wings except when the insects fly. Most bees and flies have clear glassy wings. Are the front wings and the hind wings of grasshoppers alike? What sort of wings do aphids (plant lice) have? dragonflies? mosquitoes?

Photo by G. W. Herrick

The hover fly has small but sensitive antennae

The wings of many insects such as bees, flies, moths, and butterflies are stiff and unbending. But the wings of others can be neatly folded when not in use. Watch a lady-bird beetle land or take off. Can you see it fold or unfold the transparent hind wings beneath the shiny red and black front wings? Lift the front wings of a grasshopper and see how its hind wings are folded. How many insects with folding wings can you find around your home or school?

Look carefully for different colored insect wings. Which generally have brighter-colored wings: moths or butterflies? Can you find color patterns in the wings of any flies or bees? What color are the wings of paper-wasps? Can you find the damsel-fly "blackwings"? The wings of some dragonflies are beautifully mottled, as are those of a few of the flies. In winter, collect some goldenrod ball galls (*Insect*

wings for locomotion, but their wings are of many more forms and shapes than those of the birds. Some insects—the flies, for example—have only two wings; most flying insects have four wings. But some air-borne insects have no wings. They ride on other air-borne animals, or they spin threads on which they dangle in the breeze until they reach other leaves or twigs. Can you think of an insect to illustrate each of these ways of travel? Watch different kinds of insects to see how they fly. Can you find an insect that hovers in one place like a humming-bird? one that soars like a hawk? one that can fly backward as well as forward? Can a dragonfly hover? Can you see some butterfly soar for a brief interval? Can a mosquito hover or fly backward? Can the house-fly fly backward? sideways? Watching different types of insect flight will show you something of the tremendous variety of insect wings and of the perfection of their operation. Some insects dance in swarms. Some fly singly high above the trees. Some swoop over the water for food, or to lay eggs. Still others search among the blossoms for nectar. A robber fly perches on a twig awaiting some smaller flier which it ambushes. The bee-fly hovers before a blossom like a miniature humming-bird, probing with its long hollow proboscis for the sweet nectar of the flower. And the tiny gnats or punkies (sometimes called *no-see-'ums*) may attack any warm-blooded creature. Of all the air-borne creatures, the insects are certainly the most diverse.

If you find a dead bee or wasp, look closely at its wings. They are clear, like cellophane, with tiny veins running through them. These veins are hollow and stiff, and act as the "bones" of the wing. The wings are operated by muscles in the thorax (the region between the wings). These muscles are well developed in the bees, some flies, dragon-flies, and some moths. From what you have seen, do you think that insects with a broad thorax are usually good fliers, or does a narrow thorax mean good flying? Which would indicate more muscles? Do the muscles of all flying insects move at the same rate? How can you tell? The middle C string on a piano vibrates 256 times per second. Each higher C doubles the rate of the one below it. Can you find out how fast the wings of some insects beat by finding their "buzzing tone" on the piano? How fast do you think the wings of a house fly vibrate?

to carry them to new places to live. Instead, young spiders of many kinds crawl to the top of a hummock, a blade of grass, or a twig on a shrub or tree, and spin one or more fine silky threads into the breeze. They spin their threads longer and longer until at last enough "sail" is out so that when the young spider lets go with its legs it is carried away dangling from its silken parachute. So efficient are these silky balloons that air-borne spiders have been collected on ships hundreds of miles at sea. Indeed, these spiders are perhaps the most truly air-borne of all animals, for, once they "set sail," they are completely at the mercy of the breezes.

Sometimes these spiders spin their balloons in vain. When the breeze is not strong enough to make the creatures air-borne, their silk may be draped over nearby grass and flowers. We see this silky *gossamer* early on some mornings when the light is right. It is one of nature's most delicate and beautiful displays.

Mammals

Flying squirrels

Besides birds, only two groups of New York State vertebrates (animals with backbones) can be called air-borne. These are the flying squirrels and the bats. Flying squirrels do not fly as birds and bats do, but they can glide from tree to tree. A membrane stretches from their front legs to their hind legs, and their flattened tail is well furred along the sides. In leaping, the squirrel spreads its legs and the membranes and tail act like glider wings, enabling the animal to glide from the top of one tree to the base of another 50 feet or more away.

Flying squirrels are seldom seen by New York residents, but they are much more common than you might think. Do their large eyes and apparent rarity by day tell you anything about their habits? If you had one as a pet, when would you have to watch it to see it eat or play? What would it be doing while you are playing or in school? What are such animals called?

Bats

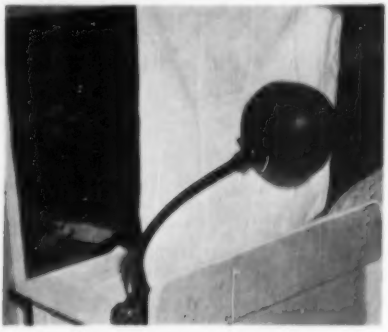
At dusk, when many mammals are preparing for a night's rest, some are just beginning their daily activities. These nocturnal animals include mice, flying squirrels, raccoons, and our only truly flying mammals, the bats. These interesting little creatures look like winged mice. They have a reputation for being ugly, for getting into peo-

Homes, the Leaflet for Winter 1953-54, will show you what they look like). Put them outdoors in a box with a screen or cheesecloth cover. Between a window and its screen is another good place for them. What sort of winged surprise emerges from these galls in the spring?

Insects sometimes use their wings for things other than flight. Crickets and katydids use their wings to communicate with each other. Have you ever seen a cricket chirp? Look closely to see whether you can find how it makes its sounds. Honeybees use their wings as fans to circulate the air in the hive. Can you discover any other interesting uses of insect wings?

Air-borne insects can also carry things which are not by themselves air-borne. Bees and some flies carry pollen from flower to flower. House flies may carry bacteria on their bodies, legs, and tongues. The elm bark beetle carries spores of the Dutch elm disease which is killing many of our stately New York elms. Pollen, spores, bacteria—most insects carry one or all of these in their flights through the ocean of air.

Insects attracted by the light behind the sheet fly through the open window at the left



If you wish to learn more about insects and their ways, you can begin by making an insect collection. Books in your library will probably help. One easy way to collect numbers of flying insects is to arrange an old sheet and a light near an open window as shown below. Open-window collecting on a warm, still night is both easy and rewarding. You may even be lucky enough to catch a huge, buzzing June beetle, or a beautiful luna, cecropia, or polyphemus moth. You will find the study of these six-legged fliers fascinating. If you start it, you will certainly want to continue.

Spiders

Most persons are familiar with the webs of spiders, but few have noticed the threads on which some spiders become air-borne. Often large numbers of young spiders are produced in a single brood. But, unlike insects and birds, spiders have no wings

York State bats are the *little brown bat*, the *big brown bat*, the *silver-haired bat*, and the *red bat*. Watch for bats as they fly around waterways, parks, and farms in the summer and autumn dusk. Do they fly in straight paths or erratic ones? Can you hear them squeak? Can you see them bump into objects? Can you find a place where they spend the day? You might look around buildings in late summer or early autumn to see whether you can find bats hanging upside down. Do they hang in light places or in the darker parts of buildings? Do bats really get in your hair, or is that just a tale? Have you heard other tales?

Photo by W. J. Hamilton, Jr.

The big brown bat may hibernate in city buildings or barns

Sounds and Smells

So far you have read chiefly about air-borne things you could see. You can't see many air-borne things—sounds and smells for example. Pause for a few seconds and listen! How many sounds can you hear? How many come from indoors? how many from outdoors? Do you hear some high-pitched sounds? others that are low-pitched? Have you ever wondered just how sounds get to your ears?

Air-borne sounds are caused by vibrations which bounce air particles back and forth between the vibrating object and your ear. These bouncing air particles cause sounds when they strike your eardrum. Sound "waves" move about 1100 feet per second, faster in warm air and slower in cold air. What would happen if there were no air between your ear and a vibrating object? If people do travel to the moon someday, how will they converse if there is no air?

The air carries many sounds which we can't even hear. Our

ple's hair, and for carrying all sorts of lice. The truth is that bats are shy, beautiful creatures, clean and covered with wonderfully soft fur. They are seldom seen in the daytime, for they spend the sunny hours hanging upside down in a hollow tree or on a leafy branch, in a barn or attic, or even behind shutters where it is dark and dry. At dusk they leave their shelters and flit over the fields and waterways in search of their air-borne food.

The wings of bats are more delicate than those of any bird, yet are strong enough to carry some of them on migration flights all the way to Mexico. Over the centuries their fingers have become long and very thin. They are the ribs of the bats' wings. Between these fingers stretches a thin but very tough, elastic membrane. Their thumb is just a tiny claw which the bat uses to help it cling to things. When they are resting, bats fold their wings neatly along their sides and hang head-downward by their feet. Can you imagine what it would be like to hang upside down for almost three-quarters of your life?

Besides having a membrane between fingers, most bats also have a membrane between their hind legs and tail. This *interfemoral membrane* is often used as a sort of net in which to catch their insect prey.

Bats are skillful fliers, though not swift ones. They are well adapted to flying in the dim light of dusk in spite of their small eyes. They emit squeaks too high-pitched to be heard by our ears, but quite audible to them. It is believed that the echoes of these squeaks enable the bats to navigate around obstacles in their paths. Experiments in dark rooms show that bats can avoid wires and other obstacles while flying in almost total darkness!

Bats, besides being air-borne, feed almost entirely on air-borne food. New York State bats eat insects, catching their prey, crushing it with their tiny, sharp teeth and eating it—all on the wing. Because it takes so much energy to fly, bats, like birds, must eat enormous quantities of food. If a bat weighed as much as 100 pounds it could eat as much as 50 pounds of insects a day! What proportion of your weight do you eat in one day?

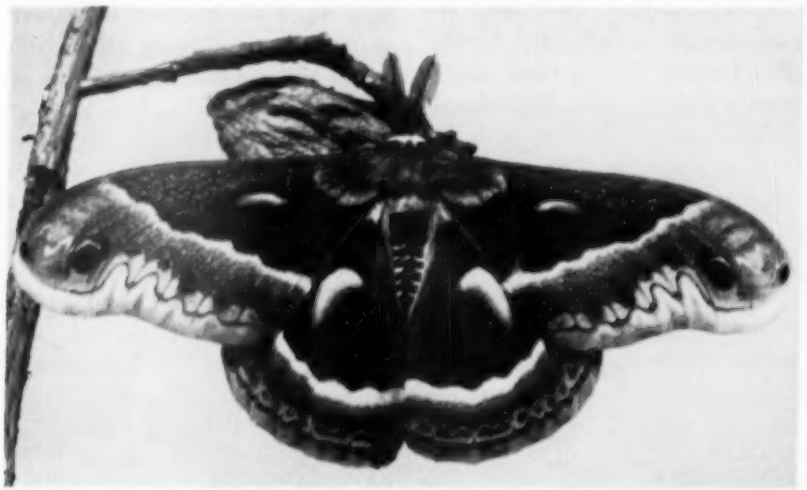
New York State bats vary in size from the tiny *pipistrelle* which weighs only 1/7 of an ounce to the large *hoary bat* which weighs as much as a white-footed mouse! Other New

But the insects probably lead all other animals in their ability to detect air-borne odors. Have you noticed how fruit-flies seem to come from everywhere when grapes are ripe, or your mother is making chili-sauce, or a ripe banana is lying in a fruit dish? A male promethea moth is said to be able to detect a female at a distance of more than 3 miles by means of scent! Ants certainly have a keen ability to locate sweet stuffs. And bees seem to have little trouble finding flowers whose nectaries are ripe.

Why are some of these animals able to detect faint odors so much better than we? For one thing, their noses have much more odor-sensitive surface than ours. In general, the longer-nosed animals, such as the deer, dog, fox, and raccoon, have a very keen sense of smell; the blunt-nosed animals, such as the cats, monkeys, and man, have a poorer sense of smell. They depend more upon sight than upon odor.

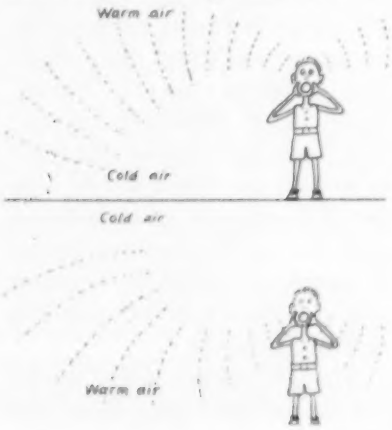
Insect antennae frequently are amazingly fitted to detect odors. The picture on page 28 shows one antenna of a male cecropia moth. These antennae are nearly one-third the length of the moth's body—much larger in comparison to its size than are our noses. Many flies have small antennae, sometimes only short

The adult cecropia moth does not eat. It lives only a few days



ears can hear vibrations as rapid as 15,000 times per second. Dogs' ears can hear sounds caused by much faster vibrations. The dog whistle which seems so silent to us may be very shrill to the ears of a dog. Many insects and bats are known to produce super-sonic sounds—too high for humans to hear. Indeed, on even the quietest evening (to us) bats and insects probably fly amid a veritable super-sonic din!

You learned in *Air Laboratories,* the Leaflet for Fall 1953, that sounds carry farther down-wind than up-wind. Temperature also affects the carrying of sound. On still nights when it is colder near the ground than it is farther up in the air, sound waves at the surface carry great distances. Sound waves which start up through the air are bent back toward the ground so a listener standing some distance away hears more sound than he would if the ground air were warm. The illustration below will help you understand this. If colder air is above warm surface air, sound is bent up off the ground and is lost to a listener at a distance. Can you figure out why sounds carry farther over water than over land in summer and autumn? Would sounds usually carry farther over water or over land in winter? Why?



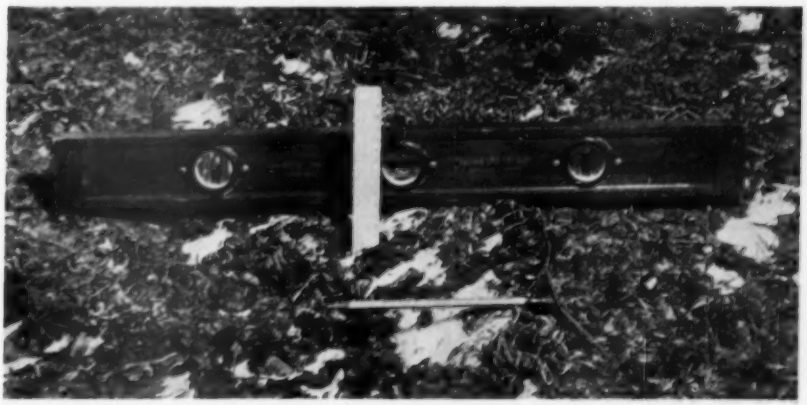
Odors are other air-borne invisibles. Just as our ears are limited in the number and loudness of sounds we hear, our noses are able to catch only a few of the odors about us. But many other animals depend upon their sense of smell to find food, locate mates or young, and sense danger. Some animals, such as deer, bears, dogs, mice, raccoons, and many others, are able to locate food at amazingly long distances. Deer can even smell a person several hundred feet away if the wind is right. Squirrels locate their stored nuts by means of smell. Trained hunting dogs follow the track of an animal for miles. Bloodhounds are well-known for their ability to trace something such as a piece of clothing or a shoe for unbelievably long distances.

Probably you have never seen a dust storm, but you have heard about them. The huge storms that occur in some parts of our country are simply large-scale effects of what you can see right around your home or school. You can see the wind blow bits of topsoil from dry fields both in winter and in summer. Cars traveling on dusty roads often raise dust clouds which cloak the roadside trees and shrubs. If you could multiply by thousands of times what you see on dusty roads or in dry fields, you would understand what dust storms are. They are really air-borne topsoil, and are serious problems in some parts of the world.

Air-borne sand is uncommon in many places in New York State, but near the Great Lakes and along the sea coasts the wind often piles sand into sand-drifts called *dunes*. These dunes migrate with wind. Sand fences have become necessary in some places to keep dunes from "air-walking" across railroad tracks, roads, and low buildings. You may not see large sand migrations in New York State, but you can see small ripples in sandy areas and even small dunes in many parts of the State. If you can find a sand dune, notice which side (windward or lee) is the steeper side. You may notice how the sand on the windward slope of the dune is itself blown off and dropped on the lee side.

Sand is sometimes used to scour the surface of metal or

In the miniature gully under the pencil, the north-facing slope was 15° F. colder than the south-facing slope



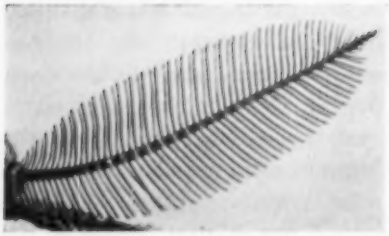


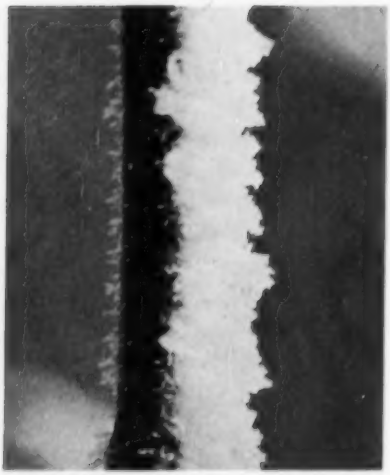
Photo by Joseph Richert

Compare this feathery cecropia antenna with the bristly antennae of the hover fly on page 21

bristles. Yet they are extremely sensitive. Does the size of antennae in insects seem to be as good an indicator of "smell-ability" as the size of nose in mammals? How many different shapes of antennae can you find among the insects? Compare the antennae of a weevil with those of a house fly. What do the antennae of a cricket look like? the antennae of a lady-bird beetle? of a butterfly? The next time a mosquito bites you, look closely at its antennae before you slap it. It is a female mosquito—only the females suck blood. Can you find out what the antennae of a male look like? Why should there be such a difference?

Snakes use their tongue to detect air-borne odors. When their tongues flick out they pick up tiny particles in the air. These are "tasted" in small pits inside the snake's mouth. So when a snake flicks its tongue in and out it is merely investigating smells as a dog does when it sniffs or a rabbit when it twitches its nose. Snakes have no ears so their air-borne signals are mainly odors. You can see why it must investigate frequently with its tongue if it can't hear as we do. Do you think snakes can harm you with their tongues? Can the tongue of any animal you know hurt you? The next time you are near a pet snake, or a garter snake from the fields, let its tongue touch your hand. Is it sharp, or very soft and feather-light?

Although your nose is not nearly so sensitive as that of most other animals, you can learn to use it much more than you do. Your outdoor hours are much more pleasant when you learn to recognize the air-borne odors around you. Just as it is great fun to *look* for insects, flowers, birds, and other things, so it is also great fun to *smell* for things. As you learn the aromas of spicebush, birch, new-mown hay, pinegroves, or even wake-robin and skunk cabbage, you will understand how the odor of many outdoor things adds to your appreciation of them.



An east wind caused the rime. The rime is to the windward.

glass or to grind letters into stone blocks. Such a process is called "sand-blasting." Air-borne sand may sand-blast objects it strikes. Such sand-blasting works more slowly than commercial sand-blasting, but over the centuries it is just as effective. Wind-blown sand has eroded away the softer rock of the walls of some old European castles, leaving the harder mortar projecting outward like the walls of a honeycomb. In several national parks in the western part of our country, are columns of rock which have been sand-blasted into weird shapes by air-borne particles. Can you find any evidence of erosion caused by air-borne soil particles around your home or school? Look for it on stone walls, on the exposed sides of old buildings, or on other things which have been standing for a long time. Which would be more likely to show sand-blasting: an object in the woods, or one in an open field?

Probably no air-borne substances are more familiar to you than rain or snow. Snow will help you learn much about air-borne objects. You can see how the snow drifts around obstacles; how particles from the windward surface of a snowdrift blow off the lee side (just as do sand particles in a dune); and how snow is distributed about buildings, hedgerows, woods, ravines, and even little hollows in the ground. Does snow pile up on the windward or the lee side of a mound or a tree or a house? Which side of a valley has the deepest snow? The picture on page 29 shows a miniature gully in which some snow has drifted. Can you tell which way the wind must have blown? If the prevailing wind in your part of New York State is from the southwest, which slope of a hill will give the best skiing? Can you think of reasons why snow would linger longer on this slope?

As you walk or ride in winter watch for wind-sculptured snowdrifts. You will find many interesting patterns in the shadowy

whiteness of drifts along fields and fencerows.

Fog is made up of air-borne water droplets. These tiny droplets drift along with the slightest breeze, falling slowly, but often travelling long distances before they strike an object, form drops, and trickle down. Sometimes these droplets are so cold that they freeze instantly when they collide with a tree, a windshield or a telephone wire. Then they form *rime ice* which looks like heavy frost. But frost frequently forms on more than one side of an upright object. Rime ice almost always forms on only *one* side. The picture on page 30 shows a twig coated with rime ice. Did the wind come from the right or from the left? What might happen to the front edge of an airplane wing when the plane flies through a cloud of such super-cooled water? Rime can be dangerous when it changes the wing shape so that the wing outline is no longer smooth.

Other Air-Bornes

Some other "air-bornes" you may wish to study are the ocean salts, the microscopic particles that cause haze, or the clouds which sculpture the skies. You may read about the atomic clouds which mushroom above the testing grounds and slowly drift away to sow their radioactive dust. Or you may wish to study man-made air-bornes such as autos, bicycles (how are these

air-borne?), balloons, airplanes, and even the liquid in your soda-straw. You have only begun to learn about the many things, living and not living, that are air-borne. In your walks or rides to and from school, and in your work and play, keep looking and listening for new discoveries. There is much more for you to see, and we'd like to hear about your experiences.

Some Helpful Books for Air-Borne Studies

This Leaflet deals with many kinds of things—all of them air-borne. A few books that will help in your studies are listed here, but you will probably find many others in your library. Don't forget books about the air and the wind, and about conservation. Past issues of the Cornell Rural School Leaflets will be useful, too, both for the information they give and for the lists of helpful books they contain.

Flowers, Fruits, Seeds (1941, 36 pages); *Seeds and Seed Travels* (1941, 36 pages). Both by Bertha M. Parker. Row, Peterson and Company, Evanston, Illinois. Helpful information and illustrations, and suggestions of things to do. Grade 4 and above.

Travelers All. By Irma E. Webber. William R. Scott, Publisher, New York City. 1944. 32 pages. How plants and animals travel.

The Book of Bird Life. By Arthur A. Allen. The Van Nostrand Company, New York City. 1930. 426 pages. General information about the characteristics and ways of American birds. Grade 6 and up.

Bird Flight. By Gordon C. Aymar. Dodd, Mead and Company, New York City. 1935. 246 pages. Excellent pictures, showing how birds' wings are constructed and how they are used. Grade 6 up.

The Junior Book of Insects. By Edwin Way Teale. E. P. Dutton and Company, New York City. 1953. 249 pages. Not a book with which to identify insects, but with much interesting information about them.

Mammals of North America. By Victor Cahalane. The Macmillan Company, New York City. 1947. 682 pages. Well-illustrated, interesting general information. Upper grades.

Animal Sounds. By George F. Mason. William Morrow and Company, New York City. 1948. 96 pages. Grade 5 and up.